BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 06004

SUBJECT: Characteristics of Lunar Surface Experiments for Apollo Missions 16-19 Case 340

DATE: June 2, 1970

FROM: J. W. Head
M. T. Yates

ABSTRACT

The characteristics of candidate scientific instruments for use on the lunar surface during Apollo missions 16-19 are defined and the experiments are discussed in terms of their potential interaction with other scientific activities, primarily geologic traverses. Modified ALSEP is considered as a single unit except for drilling and geophone deployment activities, and its impact is evaluated by analogy with Apollo 12 experience. The candidate survey experiments intended to be used in conjunction with the rover are analyzed in terms of time and activities needed to accomplish their objectives. The traverse magnetometer is seen to be the most demanding in terms of time, although its minimum objectives can be achieved in a reasonable time. The Electrical Properties experiment requires an extensive deployment and separate traverse and its interaction with the LRV is uncertain.

Examples of typical EVA timelines and scientific station timelines are used to illustrate the integration and interrelationships of the lunar surface experiments for the Apollo missions 16-19. Detailed integration of the survey experiments into a mission will depend on the specific site and the geologic exploration to be conducted there.

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MEMORANDUM FOR FILE

I. INTRODUCTION

A series of lunar surface experiments will be undertaken on Apollo missions 16-19. The purpose of this memorandum is to describe the characteristics of several experiments especially in relation to their scientific objectives and the procedures associated with the implementation of the experiment on the moon. Several of the experiments are particularly well suited for specific lunar exploration sites. The scientific rationale for exploration of possible Apollo 16-19 sites is presented in Reference 1.

The possible surface experiments are divided into three categories (Figure 1): (1) emplaced observatory instrumentation, either modified ALSEP (MALSEP) or other experiments deployed and left near the landing site, (2) emplaced instrumentation requiring astronaut participation in carrying out the experiment, but not requiring long-term monitoring, and commonly returned in part to earth, and (3) experiments intended to be used during a survey of the landing region, either hand carried or carried on the lunar roving vehicle (LRV) and used intermittently during a traverse. The possible impact of this last category of experiments on other scientific investigations, and the extent of potential interference between these experiments and the primarily geologic traverses to be undertaken are discussed in detail.

The principal sources of information used in this study were the experiment proposals and experiment implementation plans (when available). These are subject to change, revision, and reinterpretation as the hardware is designed and other aspects of a mission become finalized. Therefore many of the numbers quoted, especially any weight or volume, must be considered tentative. However, in considering the specific interfaces between an experiment and other elements of the mission or the impact of an experiment on a traverse timeline, we have attempted to stress those aspects of an experiment which should depend mainly on the experiment objectives and the nature of the phenomenon rather than on specific hardware details. Thus we have tried to make this study independent of many of the variables that will be in a constant state of flux until the flight hardware is built and tested.

II. EMPLACED OBSERVATORY INSTRUMENTATION

Modified Apollo Lunar Surface Experiments Package (MALSEP):

MALSEP will consist of a subset of the experiments listed below, together with a Central Station to provide power distribution and data handling, and a Radioisotope Thermoelectric Generator (RTG) to provide power. The various subsystems of the Central Station will be similar if not identical to those of ALSEP and will not be discussed here. Improvements will have been made in the areas of reliability and system flexibility, but these will not affect the basic experiment characteristics. Moreover, the RTG will be similar in function if not in detail to the SNAP 27 used for ALSEP.

The potential operational characteristics of MALSEP can best be estimated from the known characteristics of ALSEP. ALSEP typically carries four experiments and requires a complex two man deployment of about 90 minutes duration (Figure 2), if no special tasks are required such as drilling holes or deploying geophones. The deployment time is not particularly dependent on the nature of the experiments carried but rather on hardware details such as the number of fasteners used or whether the RTG is carried fueled or not. MALSEP should be equivalent to ALSEP in these regards and may be somewhat improved. It is doubtful whether MALSEP will carry more than four experiments per package. However, the Active Seismic and Heat Flow Experiments have unique deployment requirements which should be assessed independently of the rest of MALSEP, which can otherwise be considered as a single scientific activity.

The experiment complement for MALSEP will be chosen for each mission from the following list of experiments:

Passive Seismic Experiment (PSE): This is an ALSEP experiment which will be continued in a functionally unmodified form. It is characteristically the highest priority experiment and tends to be included on all missions. The experiment senses ground motion induced by internal processes (earthquakes, volcanism, etc.) or external processes (meteorites, man-made explosions, or impacts) and has a frequency response sufficient to detect long period surface waves and free oscillations which would characterize the deep interior of the moon.

Lunar Surface Magnetometer (LSM): Like the PSE this experiment will be a virtual copy of the ALSEP experiment flown on Apollo 12 and to be flown on Apollo 15. This should not be confused with the traverse or portable magnetometer scheduled for Apollo 14 and being considered for some of the "J" missions.

The LSM is an observatory instrument designed to monitor the temporal changes in the solar wind induced magnetic field. Coupled with data from an orbiting magnetometer it could provide information on electrical properties of the whole moon. The LSM has a limited site survey capability designed to detect gradients caused by nearby magnetic sources.

Heat Flow Experiment (HFE): This ALSEP experiment, which was to have been conducted on Apollo 13, provides the only direct measure of the moon's energy regime. It requires two 3 m holes to be drilled for the emplacement of the temperature gradient sensing probes. Thermal conductivity of the lunar material is measured _in situ_ and also on returned core samples. These measurements of temperature gradient and thermal conductivity allow the heat flow to be calculated, and from this data inferences can be made as to the present thermal state of the moon, its thermal history, and possible heat producing processes active today.

Active Seismic Experiment (ASE): This experiment will fly first on Apollo 14 and is scheduled to fly on at least one "J" mission in an unmodified form. A more sophisticated version requiring the rover for deployment of the explosive charges will be discussed later. The ALSEP version of the experiment depends on four small rocket propelled charges (grenades) to inject seismic energy into the ground at ranges from 500 ft. to 5000 ft. The resultant signal is detected by three geophones emplaced in a straight line 300 ft. long. The time of arrival of the signals at the geophones will depend on the seismic velocities of the subsurface material. This in turn will depend on the composition and degree of compaction or consolidation of the material. Specifically the thicknesses and average densities of the fragmental layers should be determined. The acoustic properties of these layers may reflect the unique environment of the moon by being extremely good transmitters of sound.

A second part of the ASE conducted by the astronauts after the geophones are deployed is the Thumper experiment. This is a small scale seismic experiment utilizing a staff (the Thumper) containing 21 explosive squibs. These are detonated by the astronaut one at a time as he walks back along the geophone string. It is not certain that the Thumper will be included in "J" mission ASE's.

Mass Spectrometer (MASPEC): The Mass Spectrometer Experiment will be newly developed for the Apollo "J" missions. The details of which sensor to use and the exact dynamic range and sensitivity of the instrument are as yet undetermined, but basically the resultant data will be the density of each molecular species present in the lunar atmosphere and the isotopic composition of the major constituents. Although radio occultation measurements have indicated that 10^{-13} atm may be an upper limit on the lunar atmospheric pressure, analyses of the returned lunar samples imply that the moon has undergone extensive outgassing during its geologic history. The detection of remnant traces of this outgassing or of similar processes going on at present would contribute directly to the understanding of the moon's peculiar chemistry.

Tidal Gravimeter (TiGr): This is the other major MALSEP experiment to be newly developed for the "J" missions, although as yet it does not have a mission assignment. As its name implies TiGr measures the acceleration of gravity; more specifically it measures the amplitude of the change in (the vertical component of) gravity due to solid body tides raised on the moon by the varying attraction of the earth and sun. The response of the moon as a whole to these tidal forces is determined by the average elastic properties (primarily, the rigidity) of the moon. Thus TiGr provides one of the few ways of sensing some aspect of the deep interior of the moon. The parameter one hopes to determine is the amplification factor, G, which represents the magnification of the actual tides over those calculated for a perfectly rigid moon. This factor can range from 1.003 for an incompressible solid moon to 1.25 for a totally liquid moon (Ref. 3). Of course the range of possible values of G for more relistic models of the lunar interior is more limited ($\sim$1.005-1.015), and the required sensitivity of the instrument is correspondinly higher (1 μgal) in order to differentiate at least crudely between competing models. Evidence from returned lunar samples points toward extremely differentiated models, i.e., deep internal structure should exist on the moon.

Another objective of TiGr not related to the moon *per se* is the search for gravitational radiation. This phenomenon has tentatively been reported on earth by correlating records from distant observing points. The use of the moon as a mass quadrupole detector for gravitational radiation in the 5 to 15 minute period range could result in discoveries of basic importance to cosmology.

Micrometeoroid Detector (MD): This experiment will be a new addition to MALSEP but has flown on two Pioneer flights. The lunar surface version will use similar detectors to observe both primary cosmic dust arriving at high angles to the surface and secondary ejecta arriving on low angle trajectories. Any data on lunar secondary ejecta will be of great value in interpreting the erosional and transportational processes that are in evidence on the moon.

The sensors are coated films that, when punctured by a small particle, produce a plasma burst that is detected by an electrode. Two of these films spaced a few centimeters apart allow the velocity of primary dust particles to be determined as well as the energy. For the secondary ejecta only the total energy of the particle will be determined. For massive particles ($>10^{-10}$gm) the momentum of the particle will also be measured by a crystal microphone.

Results from the Pioneer flights indicate that primary dust flux may be very low, on the order of one detectable event per day over the area of the sensor. The number of secondary particles that may be detected on the moon is uncertain, but lunar erosion rates now appear much lower (by a factor of 10^3) than early estimates.

Laser Ranging Retro-Reflector (LR^3): This experiment flew on Apollo 11 and is the only non-ALSEP, emplaced, observatory type experiment. The instrument consists of an array of 100 cube corner reflectors mounted in holes in an aluminum plate. These reflectors have the property of reflecting a light ray directly back along its incident path. Time of flight measurements of laser pulses bounced off the LR^3 allow extremely precise determinations (± 10 cm) to be made of the distance to the moon. This in turn is the raw data from which an improved lunar ephemeris will emerge along with various geodetic and selenodetic data such as earth and lunar radii, receiver station location, Chandler Wobble of earth, etc. It is expected that at least 2 or 3 years worth of data will be required to attempt these major analyses. The operational life of the LR^3 on the moon is not limited by any known effect, but long term degradation of optical surfaces is poorly understood.

The LR^3 aboard Apollo 11 weighed 52 lbs and required a few minutes to deploy. Future LR^3 experiments could weigh somewhat more if the number of reflectors is increased in order to allow use of small telescope ground stations. Deployment time could also increase by a minute or two to allow for deployment further from the LM, however, the basic deployment tasks—transportation, cover removal, erection, leveling, aligning in azimuth—should be quite similar to those required on Apollo 11.

III. OTHER EMPLACED INSTRUMENTATION

The second category of instrumentation requires astronaut participation in carrying out the experiment, but does not require long-term monitoring. Part or all of the instrumentation for these types of experiments are commonly returned to earth.

Far-Ultraviolet Spectroscopy/Lyman-Alpha Ultraviolet:

Objectives:

The Far-Ultraviolet Spectroscopy Experiment proposes to obtain far-ultraviolet spectra from 105-180 nanometers (nm) of galactic nebulae and the diffuse background radiation of the intersteller, interplanetary, and possibly intergalactic media. Secondary objectives are to obtain stellar spectra in this same wavelength range and to evaluate the feasibility of using the lunar surface as a location for a later astronomical observatory. Using an interference filter, the Lyman-Alpha part of the experiment should obtain photographs of the hydrogen Lyman-Alpha (HLα) emission (121.6 nm) of the geocorona, the sky background, the Milky Way star clouds, one or two nearby galaxies, and the Coma Cluster of galaxies. The experiment will add to the understanding of the earth's magnetosphere, show the suitability of a lunar observatory for astrophysical observations, check the density of intersteller hydrogen clouds, and provide evidence of the existence or non-existence of intergalactic hydrogen.

Implementation:

The experiment approach for the far-ultraviolet spectroscopy is based on using a Schmidt camera and objective grating spectrograph, with or without a venetian-blind collimator in front of the objective grating to narrow the field of view in the dispersion direction of the grating. The instrument is deployed in the shadow of the LM and various exposure sequences are initiated by the astronaut for different targets. At the end of the sequence, the film pack is removed by the astronaut and returned to earth.

The targets of interest to be observed with the collimator in place include the following:

(a) Extended nebulae
(b) One or more points in the galactic plane
(c) A point near the galactic pole
(d) One or more points in the ecliptic plane (at varying angles from the sun)
(e) A point near the ecliptic pole

The purpose of the last four target selections is to provide a means of separating the interplanetary, interstellar, and intergalactic contributions, which are expected to be concentrated toward the ecliptic plane, the galactic plane, and the galactic poles, respectively.

Targets of interest without the collimator in place include early type stars at large distances from earth in and out of the galactic plane and in the Magellanic Clouds*, planetary nebulae, external galaxies, and quasi-stellar objects.

For the Lyman-Alpha part of the experiment, the far-ultraviolet camera will be fitted with a Lyman Alpha interference filter. The astronaut aims the camera as close to 90° from earth and 180° from the sun as the site and sun elevation allow for a one hour background exposure. He then takes exposures aimed at star clouds, nearby galaxies, and a cluster of galaxies, finally removing the film pack for return to earth.

Equipment:

The equipment consists of an electronographic Schmidt camera, with a lithium flouride correction plate of 3" aperture, f/1.0, and objective grating (1200 lines/mm), a venetian-blind collimator, and a film transport. These are mounted on a tripod stand with equatorial mount and clock drive, adjusted for the lunar sidereal rate and the latitude of the particular landing site. The Lyman-Alpha experiment filter will be one already flown successfully on OAO-A2.

Operation:

The astronaut removes the instrument from the LM and sets it up in the shadow of the LM so that it will be protected from exposure to direct sunlight. For the far-ultraviolet part of the experiment he then points the instrument at the area of interest of the sky and initiates a sequence of exposures. At the end of the sequence, the astronaut points the instrument at the next target and repeats the procedure. After the series of targets with collimator in place have all been observed, the astronaut removes the collimator and goes through the list of targets to be observed without the collimator. At the completion of the lunar stay, the astronaut removes the film container from the instrument and carries it aboard the ascent stage of the LM for return to earth.

The tentative sequence of exposures are 1, 4, 16, and 64 minutes for diffuse nebulae and exposures not using the collimator, and 4, 16, 64, and 256 minutes for exposures of the diffuse background using the collimator. The astronaut would need only to point the instrument, and then press a button to initiate the four-exposure seqeunce (a selector switch would be provided to select a "short" or "long" sequence); a yellow light would then come on to indicate that the exposures are in progress.

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*Photography of the Magellanic Clouds will require a southern hemisphere landing site of at least 15° south latitude.

At the end of the exposure sequence, a green light would come on, indicating that the instrument is ready to go to the next target. A switch is also provided for turning on the high voltage and monitor at the beginning of the observing period; these would be left on for the duration of the observations.

The filter for the HLα phase of the experiment is placed on the camera at some time during the lunar surface stay. The astronaut will then aim the camera at the earth and take several exposures of about 10 minutes each. He will then turn the camera away from the earth and the sun for a one hour background exposure. Depending on the orientation (site location, time of year, time of month) he then takes exposures aimed at star clouds, nearby galaxies, and a cluster of galaxies. If time is available, a second one hour exposure should be made on the sky background. The astronaut finally removes the film pack for return to earth. An automatic camera setting, exposure time, and semi-automatic film advance arrangement will be employed.

Interfaces:

The major interface problems with this experiment lie in integrating the deployment and operation of the instrument with other scientific activities during the lunar surface stay. The experiment requires very careful initial deployment and orientation as well as continued astronaut participation in retargeting and initiating exposure sequences. The continual return of the astronaut to the instrument for these activities, as well as the retrieval of the film at the end of the experiment, requires that the instrument be in close proximity to an area frequently visited, i.e., the LM.

A similar problem exists in terms of length of exposure sequences. One exposure sequence for the far-ultraviolet, aimed at a diffuse background and using the collimator, should be approximately five hours and forty minutes in duration, for optimum experimental results. Since this length of time is of the order expected for EVA's, and since at least eleven exposure sequences are desired, radical changes will have to be made either in length of exposure sequences, number of targets, or extent of astronaut participation in the experiment. Even if exposure sequence times of one hour and twenty-five minutes are used (typical for targets of diffuse nebulae without the collimator), the astronaut will probably not be in the vicinity of the camera at the end of each sequence because of traverse activities away from the vicinity of the LM.

Cosmic Ray Experiment:

Objective:

The Cosmic Ray Experiment will employ high resolution plastic track detectors to determine the charge and energy spectrum of cosmic rays with atomic number $Z>8$ at energies between $\sim$10 and 200 MeV/nucleon. Major effort will be directed toward identifying individual isotopes, an achievement which has previously been accomplished by other methods only for hydrogen and helium. These studies of heavy cosmic rays beyond the earth's atmosphere and magnetic field should provide unique information on the composition of cosmic ray sources that will bear on their origin and on the nature of stellar nucleosynthesis.

Implementation:

Several detector stacks will be exposed to cosmic rays outside the spacecraft for about 100 hrs. Upon return to earth, the sheets will be etched and the lengths of the resulting conical tracks along cosmic ray trajectories will be measured with an optical microscope. Energies, charges, and masses of cosmic rays with atomic number greater than 8 will be determined from these measurements.

Equipment:

The equipment consists of several identical stacks (Detector Stacks) of plastic detector material which will be mounted on a frame that attaches to the LM exterior. Each Detector Stack will contain 40 sheets of Lexan polycarbonate resin (0.010" thick). The Lexan sheets measure 6"x10" and are held in a picture frame. The plastic and the picture frame comprise the Detector Stack Assembly. The Detector Stacks are attached to the Detector Frame in such a fashion that the astronaut can remove the stacks during the EVA and place them in the LM. At present, total weight of the experiment is approximately 20 pounds, of which approximately 8 pounds (Detector Stacks) will be returned to earth. Other detector materials such as mica and glass may also be used as detector material. These would be treated in a manner similar to the Lexan.

Operation:

The Detector Stack Assembly is attached to the LM before launch. The astronaut must release the stacks from the LM and store them in the LM for return to earth at the end of an EVA period.

Interfaces:

The Cosmic Ray Experiment requires minimal astronaut participation. Releasing and stowing the Detector Stacks should be easily accomplished in a few minutes at the termination of any nominal EVA period. Since most of the exposure time may be acquired during translunar coast, it is not mandatory to wait until the last EVA to retrieve the stack, although maximum exposure time is desirable.

Placement of the assembly on the LM must be made so that the Detector Stacks are shielded from the sun and from RCS thruster plumes so as to keep the stack temperature below 120°F. This may be difficult in view of the barbecue mode of LM/CSM thermal control during translunar coast.

IV. SITE SURVEY EXPERIMENTS

This category of experiments includes those which are intended to be used during a survey of the landing region, either hand carried or carried on the Lunar Roving Vehicle (LRV). These experiments are used intermittantly during a traverse. The possible impact of this category of experiments on other scientific investigations and the extent of potential interference between these experiments and the primarily geologic traverses to be undertaken are discussed in detail.

Surface Electrical Properties (SEP):

Objective:

This experiment is designed to detect discontinuities in the electrical properties of the lunar subsurface (to depths of a few kilometers) using radio interferometry. The primary cause of such discontinuities would be the presence of liquid water.

Implementation:

A stationary transmitter and a hand carried receiver establish the base line for the interferometry. The continuous wave transmitter is deployed about 100 m from the LM and broadcasts one watt multiplexed among eight to ten discrete frequencies between 0.5 and 32 MHz (wavelengths of 10 to 600 m). The field strength measured at the variable receiver position is a function of (among other things), the depth to a discontinuity in the electrical properties (dielectric constant, conductivity) of the subsurface rocks. The range and azimuth from the receiver to the transmitter is measured automatically by a separate radio triangulation system.

Equipment:

The transmitter consists of a 20 cm x 20 cm x 10 cm electronics package, an array of eight to ten dipole antennas (two 70 m lengths rolled onto spools) and three 3 m diameter loop antennas two of which are stowed in the dipole spools and one in the electronics box. These loop antennas are the ranging system transmitting antennas while the dipoles are the interferometry antennas.

The receiver is carried by the astronaut and consists of three orthogonal antennas, a tape recorder, and the receiver electronics. The unstowed volume (including antennas) is about one cubic foot and the assembly wieghs 13.5 lbs.

The experiment hardware, including a mu-metal box for returning the tape to earth, can be stored in 1 cubic foot for less than 25 lbs.

Operation:

Although execution of this experiment requires that the receiver be carried 2 or 3 km along a line normal to the axis of the transmitter dipoles, the experiment was not originally designed as a roving vehicle traverse experiment and in fact may be incompatible with the rover due to electromagnetic interference. Regardless of whether the rover can be used during the experiment, the initial deployment of the antenna arrays and the retrieval of the tape after the traverse could take one astronaut 23 min or two astronatus 15 min (optimistic estimates). Figure 3 shows a plan view of the experiment deployment and a detailed outline of the deployment sequence. In addition to the deployment of the instrument, the traverse with the receiver would require a minimum of 1 hour at a walking speed of 4 km/hr.

Interfaces:

Since the Surface Electrical Properties Experiment is presently being considered for the J-missions (Apollo 16-19), the most critical experiment interface will be with the lunar roving vehicle. Although the rover will by design have no functional interfaces with any experiment, it will be used extensively throughout the surface staytime on these missions, and obviously such a time consuming and complex experiment as SEP must be reconciled with it both in the timeline and operationally.

Present estimates of the duration of J-mission type EVA periods and scientific activities indicate that over 40% of EVA time will be used in operational overhead. Twenty percent of the time remaining for scientific activities would be consumed by SEP deployment and a walking traverse. Of course, the SEP traverse may be able to double as an initial geological reconnoiter. However, the fact that the SEP traverse must run approximately normal to the dipole antennas and a rather bulky receiver must be carried would limit other activities such as collecting samples, photographing, consulting maps, etc. A further constraint on the SEP traverse may be a finite battery life and/or tape length obviating any significant detours from a straight line route.

The ability to use the rover for an SEP traverse will depend on possible electromagnetic interference (either active or passive) from the rover. Since the SEP measures field strength (ideally to 1% accuracy), any local perturbation or EM source could seriously degrade the experiment. It should be noted that the rover design will not be subject to any EMI requirements nor will the electromagnetic environment of the LRV necessarily be determined. Thus the responsibility for EM compatibility rests solely on the experiment, and the question of whether the rover would interfere with the functioning of the experiment is presently unanswered. However, the need to measure field strength on a relatively continuous basis (i.e., at intervals short compared to the 10 to 600 m wavelengths involved) would seem to obviate the use of rover for the SEP traverse.

Lunar Portable Magnetometer Experiment (LPM):

Objective:

The objective of this experiment is to determine the anomalous magnetic field along a traverse. The anomalous field is defined as the locally measured field less any regional field and is corrected for any temporal field variations. It is presumably related to the local geologic features (dikes, lava flows, compositional boundaries) as well as the strength of the paleomagnetic ambient field.

Implementation:

Three orthogonal components of the magnetic field are measured at several traverse stations (at least three). The temporal variation of the field is subtracted using data from an emplaced stationary magnetometer or from an orbiting magnetometer (Explorer 35) and any remaining difference in the field at two points is ascribed to spatial variations (i.e., a magnetic anomaly). The location of the anomaly source can be estimated from the measured spatial gradients.

Equipment:

Three orthogonally oriented flux gate magnetometers measure the vector magnetic field. These sensors are contained in a cube about 10 cm on a side which is mounted on a tripod and connected by a 50 foot flat cable to an electronics package. This package (about 10x10x20 cm) contains the drive circuitry for the sensors, the output amplifiers and filters, and the read-out meters (three ammeters calibrated in nanotesla). The tripod has a sun compass and bubble level for rough orientation (±3°) of the sensor head.

Operation:

The equipment and procedures described here are based on the experiment proposed for Apollo 14 only. Present plans indicate that this experiment will be similar in hardware and operational requirements to a "J" mission traverse magnetometer, therefore constraints presently identified for the Apollo 14 mission have in this report been extrapolated to rover missions.

The Lunar Portable Magnetometer Experiment measures the ambient magnetic field at a single point. The first measurement station is more complex than succeeding stations because the sensors must be calibrated by successive measurements in different orientations, (similar to the ALSEP LSM sensor-flip and calibrate sequence). The first station requires four 30 m round trips from the electronics package (presumably mounted on the LRV) to the sensor located on the tripod away from magnetic perturbations caused by the LRV or the astronaut. At each return to the tripod the sensor is removed from the tripod, rotated to a new orientation, replaced on the tripod and locked in place. The tripod must then be releveled and aligned. The astronaut then returns to the LRV to read the meters.

Subsequent measurements require only two round trips from the LRV to the tripod, one to emplace the sensor and one to retrieve the sensor. The sensor and tripod can be discarded after the last reading.

Interfaces:

As with the Surface Electrical Properties Experiment, the Lunar Portable Magnetometer is susceptible to electromagnetic interference. The present 50 ft cable is sized for the magnetic fields estimated to be due to the astronaut (actually due to the PLSS), and this distance may actually decrease contingent upon measurements of the fields associated with the astronaut. The actual length of the cable may not be the important parameter, however. Assuming a modest walking rate of 5.5 km/hr (5 ft/sec), a 100 ft round trip need only take 20 sec, and four of them perhaps a minute and a half. More important may be the necessity to stow and unstow a lengthy cable each time a measurement is taken at a new station. The traverse aspect of the experiment, that is many stations distributed over a wide area, may prove exceptionally time-consuming. A minimum experiment, for instance three widely separated measurements, may be all that is desirable in the context of the total scientific traverse. Such an experiment would be designed to detect field gradients on a regional scale, rather than the more detailed local survey.

The interface between the LPM experiment and the astronaut is also complex and of long duration. The tasks associated with one measurement—offload, carry out, set up, align, level, walk back, read meters, walk out, take down, carry back, onload—are similar to deploying one ALSEP experiment and by analogy with the LSM deployment on Apollo 12 (which also required a 50 ft separation from EM sources) one LPM measurement station could take 10 to 15 minutes assuming the cable wind-up reel works expeditiously. The first station with its additional calibration tasks could require 20 minutes. Although most of the deployment tasks are serial and cannot be significantly reduced by using both crewmen, some reduction in astronaut participation could be achieved at great expense in instrument complexity by using a retrievable memory core or similar recording device. Since the data is not readily reducible in real time (due to the time variations), it does not need to be transmitted in real time, although watching the needles move is an indication that the instrument is working.

If the presently conceived schedule of experiments is adhered to, the requirement to have a stationary magnetometer in operation simultaneous with the traverse experiment is hardly constraining. Apollo 14 plans to utilize the Apollo 12 LSM, Explorer 35, or both. Apollo 16 will use the magnetometer scheduled for the surface experiment payload of Apollo 16 itself (with the Apollo 15 LSM as backup). Historically the ALSEP experiments are deployed and activated (if contamination is no problem) prior to any geologic investigations.

Lunar Seismic Profiling Experiment (LSP):

<u>Objective:</u>

This experiment will use reflection/refraction seismology to determine the seismic velocity structure in the upper few kilometers of the moon in the vicinity of the landing site. The velocity structure is a function of the density (composition and compaction) of the underlying material as well as the subsurface expressions of geologic features.

Implementation:

Explosive charges emplaced at preselected locations during the geologic traverses are detonated after the manned phase of the mission is over. The resulting seismic waves are detected by a geophone array deployed near the LM, and the data (ground motion as a function of time) is telemetered to earth using the ALSEP Central Station.

A much smaller scale experiment may be incorporated into the main experiment by using a Thumper (previously described) to inject seismic energy into the ground. This is not a part of the LSP at present, however.

Equipment:

The four geophones are planned to be similar (if not identical) to ALSEP hardware. Geophones are very small, lightweight, high frequency seismometers using a magnet/coil assembly to measure ground velocity. Each one will weigh less than 0.5 lbs. These will be connected via 450 m of cable (<10 lbs) to the electronics package which is contained in the ALSEP Central Station. The ten explosive charges will range from 1/8 to 10 lbs with a total weight of about 30 lbs. They will be detonated one at a time either by ground command or by self-contained clock (probably the latter). Should a clock be used then the charges must each contain a transmitter whose cessation will accurately determine the time of detonation. The weight of the detonation device is not included in the 30 lb total and could amount to 1 lb per charge.

The Thumper, should it be used, would be left-over ALSEP equipment. It is a staff containing 21 Apollo Standard Initiators in its base. Arm and fire switches allow the astronaut to individually fire these charges each of which is roughly equivalent to a .22 caliber bullet.

Although the present ALSEP ASE uses a 10,600 bit/s data rate, the LSP will require only the normal 1,060 bit/s ALSEP rate. This will be accomplished by reducing the data bandwidth to 20 Hz and transmitting the full data stream from only one geophone. The data from the other three geophones will be compressed and only the zero crossing information or the maximum amplitude will be transmitted.

Operation:

The deployment of the LSP will be carried out in two phases (Figure 4). First, the geophones will be laid out in a triangular array 160 m on a side with the fourth geophone placed in the center. These will be hard wired to the MALSEP Central

Station. Later, during rover traverses the explosive charges will be deployed at spots preselected to give a spread in range and azimuth to the geophones. These locations will be chosen for the specific landing site commensurate with the traverses planned for the geologic investigation.

At the present time there is no requirement to do anything more complex than place the charge on the surface and possibly throw a switch to initiate a clock or arm the explosive in some fail-safe, reliable manner. However, it is well known that one can greatly increase the seismic coupling obtainable from an explosive charge by burying it. At present though it seems doubtful that maximum coupling efficiency will be required to achieve adequate signals.

The task of deploying the geophones will probably be considerably more time consuming than the equivalent task in the Apollo 14 Active Seismic Experiment. Figure 4 shows the two geophone arrays for the ASE and LSP. Not only will the LSP require three times the amount of walking to lay out the geophones but the geometry of the array will be more difficult to determine in the LSP than in the straight line configuration ASE. MSC is presently alloting 15 min for the geophone deployment on Apollo 14. Based on this estimate it would not be unreasonable to assume that the geophone deployment for the LSP would take half an hour, including photographing the array or in some other way determining the inter-geophone spacing and angles. Should a Thumper experiment be conducted after the geophones are deployed this could double the time devoted to this phase of the LSP.

Interfaces:

The Lunar Seismic Profiling Experiment interface with the rover and the operations associated with the geologic traverses should be relatively simple. The ten charges can be stowed individually in smaller units rather than having to allocate a single volume for the entire 30 lbs. Although this would require more time to load the rover, it may be the only way to use some of the payload space.

Deployment of the charges should be quite simple: drop it on the ground, remove a safing device, and arm the charge. The need to know the exact time of detonation may require a rough aligning of an antenna or some form of positioning. The detonating device will incorporate a small receiver or transmitter so that the charge can either 1) be detonated by command from ALSEP or earth, or 2) mark the detonation time by transmission termination. The choice depends on (among other things) whether it is possible to establish radio links on the moon without line-of-sight, since obviously a system incorporating a transmitter would have to transmit to ALSEP as opposed to earth. A requirement for line-of-sight between ALSEP and the charges would seriously constrain their location and compromise the experiment.

The protection of the astronauts and the spacecraft against a misfire will certainly be a strong constraint on the design and testing of this experiment. However, as is the case with the ASE, the safety provisions would not be expected to particularly complicate the deployment or execution of the experiment.

An important difference between the ASE and the LSP which will complicate the deployment is the fact that the ASE is instrumented to determine the range and azimuth of the shot points. In the LSP these must be determined in real time using the rover naviation aids (gyro compass and odometer), or landmark tracking (astronaut plus map plus real time television). The range accuracy requirement of the ASE was originally ±5% (later tightened to ±3% since it was easily obtainable) and this should be acceptable for the LSP. For comparison the rover navigation specification calls for a range accuracy of ±10% and a bearing accuracy of ±3% at a range of 5 km.

Another interface that may become important to this experiment is that of charge emplacement with respect to the planned geological traverse. The ten charges should be placed at locations related to the geologic structures in the vicinity. Hopefully the geologic traverse will be planned to investigate the surface expressions of these structures (domes, cones, craters, rilles, ridges, etc.) and the two experiments will complement each other. However, a conflict of interest is possible and in that event the geologic requirements should take precedence.

Lunar Traverse Gravimeter:

Objective:

This experiment will determine the relative acceleration of gravity at a discrete set of points along the rover traverse. The datum to which these measurements are referred will, if possible, be related to an earth-based gravity station. The gravity anomalies so determined will be used in the interpretation of local geologic structures and topographic relief.

Implementation:

The experiment utilizes a gravimeter calibrated on earth to refer local lunar gravity values (measured along the traverses) to a base station measurement made at or near the LM. This same gravimeter may be used in a lower sensitivity, higher dynamic range mode to refer the base station value ($\sim$162 cm/s^2 or gals) to an absolute value on earth. In addition to the gravity data, the location of each station must be determined, specifically the elevation of the station relative to the LM and the position of each station on the geologic map.

Equipment:

The gravimeter sensor itself will either be a vibrating string accelerometer or an electrostatic force rebalance accelerometer. In any case it is a very small, lightweight, large dynamic range accelerometer that was originally designed as a part of a missle guidance system. Unfortunately the shift from a 0-50g accelerometer to a 0-100mgal (1 mgal $\approx 10^{-6}$g) gravimeter requires the addition of some 25 pounds of thermal, structural, data, and power subsystems. The exact configuration of the instrument will depend to some extent on which sensor is chosen, but for the most part the experiment is insensitive to this decision.

One component of the experiment that is as yet undetermined is the battery. The gravimeter is given an absolute gravity calibration on the earth prior to flight and the maintenance of this calibration requires that the instrument maintain close thermal control from the time of last calibration on earth until the lunar measurements are completed. This time period could be several months. Although an external power source could be used for most of that time, internal power just from the day prior to launch requires an 11 pound battery. This severe requirement may result in the deletion of this part of the experiment, which was designed to measure regional differences in gravity and to act as ground truth for the Orbiter gravity data. The traverse part of the experiment requires thermal control only from 24 hrs before the first measurement until the traverses are over.

Since the data from the gravimeter experiment will consist of a discrete set of gravity values, these are most easily stored in a memory core which is then returned to earth for readout. The positioning of the gravity station will be aided by the astronaut's verbal description of the station location. The actual traverse stations will be reconstruected on the ground post-flight from a variety of data including surface photography. The station's (relative) elevation is a critical adjunct to the gravity data itself and must be provided to at least $\pm$15 m if the gravity data is to be meaningfully interpreted. Although it is possible to incorporate a high accuracy survey system into the gravimeter experiment, the present experiment concept does not include such a device, and the required elevation control will have to come from orbital (or possibly surface) photography.

Operation:

A measurement sequence is initiated at each gravity station which consists of removing the gravimeter from the rover, placing it on the surface, uncaging the sensor, allowing time for equilibration, data readout and recording. An alternative design calls for the sensor to be rigidly mounted in the gravimeter and for separate off-level sensors to measure the orientation of the package on the surface (to about 3 mrad) so that the vertical component of gravity can be determined. The station is completed by returning the gravimeter to its stowed configuration on the rover.

Since precise leveling of the instrument will either be automatic (gimbals) or not required, the time required for a station need be no more than 3 minutes (optimistically), not counting dismounting or remounting the rover. It is presently anticipated that a sufficient number of stops will be made for geologic sampling so that stops need not be scheduled solely for gravimeter stations, however, this could change based on the actual traverse plans. Since no data is transmitted in real time the gravimeter experiment should have no unanticipated impact on the mission.

In addition to the individual station times the conclusion of the experiment will entail removing the memory core and storing it for return to earth, possibly a 10 minute task.

Interfaces:

The major interface between the traverse gravimeter experiment and the rest of the mission will be simply the total time allotted for gravity stations, that is time per station times the number of stations. In the absence of high fidelity simulations, it is unreasonable to consider the 3 min/station figure as more than a guess. However, the number of stations that would constitute an acceptable survey depends on the character of the features to be investigated and on the total uncertainty in the reduced gravity measurements, and these are presently estimable. For example, at Marius Hills present preliminary mission planning calls for approximately 30 scientific stations distributed over about 75 km^2. Ideally in such an area where the interesting features are on the order of one square kilometer in area, one would like to conduct a gravity survey on a 0.1 mgal scale. This would allow highly detailed gravimetric interpretation of the geologic features in the region. Unfortunately, such a detailed survey of the whole area to be explored would require several thousand stations. Of course, short profiles of selected regions could be done in more detail while the region as a whole was surveyed at a lower accuracy. For example, 30 stations per 75 km^2 represents an average station density of about 0.6 stations/km along the traverses. This in turn determines the accuracy required for an adequate regional survey, which for this station density would be on the order of ±1 mgal based on typical terrestrial surveys (Fig. 5). If there were sufficient time in the mission at Marius Hills to study one feature in detail, one could traverse across the narrow ridge material. This would entail perhaps ten stations, one every 30 m, and the traverse would require from 45 minutes to an hour to accomplish. For a survey of this detail the accuracy of the reduced gravity measurements should be on the order of ±0.1 mgal.

The elevation control needed for this experiment is in direct proportion to the required survey accuracy, and whether this control is obtainable may determine whether detailed surveys are feasible. The oft quoted optimum elevation control is ±1 m relative to an arbitrary datum (the LM, say). This represents a free air correction to measured gravity of ±0.2 mgal or a Bouger correction of ±0.05 mgal (for a surface rock density of 3.3 gm/cm^3).

The appropriate correction to apply to the gravity measurements is, in this case, the Bouger correction since it takes into account not only the change in distance from the center of mass of the moon, but also the additional mass underneath a gravity station, when it is taken, say, on a mountain. Thus ±10 m elevation control would result in reduced gravity measurements good to ±0.5 mgal, assuming adequate instrument stability. This elevation control would then be sufficient for a regional survey at a ±1 mgal level of accuracy. Reliance on Bouger anomalies requires that the average density of the structures traversed over be determinable from the returned samples and of course obviates the use of gravity measurements to determine surface densities.

Elevation control of ±10 m over distances of 10 km is unobtainable from Orbiter photography due to uncertainty in orientation of the spacecraft. Therefore, station elevations must either be determined in real time as part of the experiment, or provisions must be made to determine them from later photography. This latter method seems the most practical using the panoramic camera and metric camera to be mounted in the Service Module on Apollo missions 16-18. This camera system is capable of photographing the whole region of exploration of Marius Hills at a resolution of ±2 m and with an elevation control capability of something like ±10 to ±15 m. Recent work at USGS/Flagstaff suggests that elevation determinations good to ±5 m may be achievable using Hasselblad panoramic coverage taken during the traverse for geometric control and Orbiter photos for baseline determinations.

In summary the traverse gravimeter experiment can be accomplished during presently planned "J" type missions at a cost of 3 min/station, or a total of about 1.5 hour/mission. In addition, photography of the surveyed area must be capable of determining the relative elevation of the stations to something like ± 10 m to ± 15 m minimum. This need not be done simultaneous with the surface phase of the mission, nor actually need it be done on the same mission. Better elevation control (± 1 m to ± 5 m) would allow better interpretation of the data (i.e., surface densities need not be assumed) and if time allowed larger scale, more detailed surveys of selected features.

V. SUMMARY AND CONCLUSIONS

The possible lunar surface scientific experiments for Apollo missions 16-19 have been divided into three categories (Figure 1): (1) Emplaced observatory instrumentation, either modified ALSEP (MALSEP) or other experiments deployed and left near the landing site, (2) emplaced instrumentation requiring astronaut participation in carrying out the experiment, but not requiring long-term monitoring, and commonly returned in part to earth, and (3) experiments intended to be used during a survey of the landing region, either hand carried or carried on the lunar roving vehicle (LRV) and used intermittently during a traverse. The physical characteristics of these instruments are outlined in Figure 6.

It is important to estimate the duration of various scientific experiment activities for advanced missions so that the impact on EVA timelines can be understood. Information such as this provides the data necessary to make trade-offs for surface exploration planning. Three areas other than travel compete for time during any given EVA period; operations, field geologic investigations, and deployment and data gathering from scientific instrumentation. Surface operations at the beginning and at the end of each EVA period relate mainly to preparation for surface scientific exploration and are outlined elsewhere (Ref. 4). Similarly, operational activities during the EVA periods consist predominantly of LRV-related navigational tasks and ingress/egress activities, as well as preparation for voice and TV communications (Ref. 5). Field geologic investigations require certain types of activities and activity sequences, depending on the specific landing site and scientific station. Estimates of these activities and their duration can be found in Reference 6. The time required for deployment and data gathering from scientific instrumentation is related to the category of the experiment. Emplaced observatory experiments (generally MALSEP) are characteristically deployed during the first EVA. ALSEP deployment experience (both astronauts, 90 minutes) should not be unreasonable for MALSEP without Heat Flow or Active Seismic Experiments. For experiment complements that require the drilling of holes or the emplacement of geophone arrays, an additional 20 to 40 minutes should be added. Incorporation of both these experiments in a mission would require less then an hour of additional time for their deployment, since some tasks could be accomplished in parallel by the two astronauts. However, for EVA timeline considerations a conservative estimate of one hour would be appropriate.

Emplaced instrumentation requiring astronaut participation in carrying out the experiment, and commonly returned in part to earth often requires astronaut participation for deployment (Far UV), and for retrieval and stowage of data (Far UV, Cosmic Ray). The estimated time requirements for these experiments have been discussed previously, and it is clear that the Far UV experiment will have to be reconciled with the overall mission.

Experiments intended to be used during a survey of the landing region may affect the timeline in two ways. If an experiment such as Surface Electrical Properties is to be carried out independently on an LRV traverse, a considerable block of time must be allotted for a walking traverse to conduct this experiment. Other experiments are intended to be used during the LRV traverses and affect the timeline through the number of times used during the traverse (Figure 7), and the tasks and activities associated with each experiment when it is performed at a specific station (Figures 7, 8, and 9). As presently conceived, the Lunar Traverse Gravimeter will have little impact on the timeline since the experiment is semi-automated and requires only manual off loading and restowing on the LRV. Figure 9 indicates the three minute duration gravity station as a separate item, although it can readily be integrated elsewhere into the operations overhead period. Similarly, the traverse portion of the Lunar Seismic Profiling Experiment should have little impact on the timeline (Figure 9) since the actual experiment is conducted after the mission as part of MALSEP. The added complexity of whatever timing and detonation devices are chosen may increase the required astronaut participation in this experiment. The use of the traverse magnetometer at a specific station will greatly increase the time needed for that stop (Figure 9), and a compromise will have to be made concerning the total number of magnetometer stations per traverse. Four magnetometer stations per traverse might be a reasonable maximum usage of this experiment, however, all the site survey instruments must be integrated into a mission not only on a site specific basis, but also on a station specific basis. Additional data on the deployment time required for the LPM should be avaialble in advance since a similar magnetometer experiment is scheduled to fly on Apollo 14. The present state of knowledge of deployment times for the three LRV-carried survey instruments and their relationships to scientific stop activities are summarized in Figure 9. Other combinations of instrument usage are obviously possible. The block of time for geologic investigations at stations where the astronaut egresses would be a minimum of 12 min (one documented sample, one trench sample or core sample, panoramic photography). A typical time for this investigation at a station would be 20-25 min and a maximum time at a very complex station could be an hour.

The deployment and use of the traverse magnetometer, the seismic profiling experiment, and the traverse gravimeter are dependent on the geology of the landing site and the location of the traverse stations in relation to the geology. Also these three rover traverse experiments interact constructively in that more than three times the information is gained by conducting all three types of surveys in the same area. Gravity and seismic surveys are especially complementary; gravity providing shapes and contours while seismic profiles determine densities and depths. Mission assignments should reflect this fact.

The integration of lunar surface instrumentation, especially the Surface Electrical Properties Experiment, into a mission will require adjustment of the EVA timelines to reflect the peculiar requirements of the experiments and their priorities. Figure 10 illustrates several possible alternatives for the deployment and execution of scientific experiments and LRV traverses. EVA I, Cases 1A, B, and EVA II, Case 1 illustrate a mission timeline where no Surface Electrical Properties (SEP) Experiment is deployed. EVA I Cases 2A, B, and EVA II, Case 1, illustrate a mission timeline where the SEP experiment is deployed on a walking traverse subsequent to LRV preparation. In both cases, timeline constraints result in inadequate time for completion of a walking traverse of the length desirable for the SEP experiment. If the SEP experiment proves to be compatible with the LRV, a traverse of sufficient length could be carried out in this time framework. Alternatively, a full SEP experiment walking traverse could be achieved on EVA I by delaying the deployment of the LRV until EVA II (EVA I, Cases 3A, B; EVA II, Case 2). A similar compromise might be reached by carrying out a normal LRV deployment and traverse on EVA I (Cases 1A, B), and delaying the SEP experiment walking traverse until the second EVA (EVA II, Case 3). In all cases outlined here, the EVA III traverse would remain unchanged. Final resolution of these alternatives will be aided by an understanding of the SEP experiment interface with the LRV and the possibility of combining the SEP traverse with an LRV traverse.

Figure 11 illustrates a recent experiment/mission matrix prepared by MSC (S&AD). Although this mission assignment matrix will undoubtedly change, it reflects the present estimates of development times and total number of experiments available.

J. W. Head

M. T. Yates

2015-$\frac{\text{JWH}}{\text{MTY}}$-kmj

Attachment
References
Figures 1-11

REFERENCES

1. J. W. Head, "Scientific Rationale Summaries for Apollo Candidate Lunar Exploration Landing Sites," Bellcomm Memorandum for File, B70 03034, Case 340, March 11, 1970.

2. MSC Document, MSC-01266, "Apollo Program (Phase 1 Lunar Exploration), Mission Definition," December 1, 1969.

3. J. C. Harrison, "An Analysis of the Lunar Tides," Journal of Geophysical Research, 68, July 15, 1963, pp 4269-4280.

4. P. Benjamin, "Revision of Operational Constraints for J Mission Traverse Planning, Bellcomm Memorandum for File, B70 04024, Case 320, April 7, 1970.

5. J. C. Slaybaugh, "Modular Timeline Elements for Lunar Roving Vehicle Traverse Station Stops," Bellcomm Memorandum for File, B70 03072, Case 320, March 24, 1970.

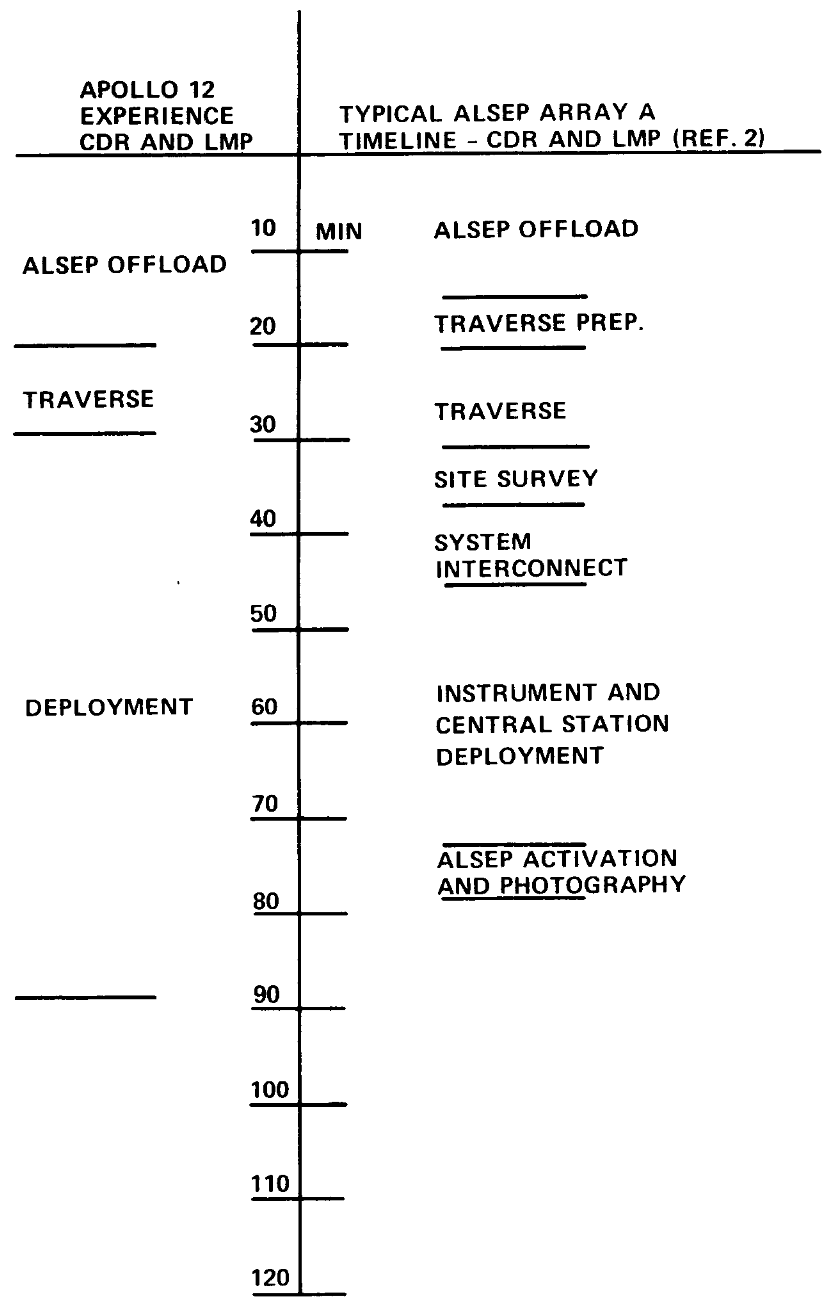
6. J. W. Head, "J-Mission Traverse Planning: The Implication of Apollo 13 Traverse Scientific Activities," Bellcomm Memorandum for File, B70 04003, Case 340, April 2, 1970.

TYPE OF EXPERIMENT*

EXPERIMENT NAME AND NUMBER			EMPLACED OBSERVATORY	OTHER EMPLACED	SITE SURVEY EXPERIMENTS: INDEPENDENT TRAVERSE	SITE SURVEY EXPERIMENTS: ROVING VEHICLE TRAVERSE
S-031	PASSIVE SEISMIC EXPERIMENT	MODIFIED ALSEP	X			
S-033	ACTIVE SEISMIC EXPERIMENT	MODIFIED ALSEP	X········	···X (THUMPER)		
S-034	LUNAR SURFACE MAGNETOMETER	MODIFIED ALSEP	X			
S-037	LUNAR HEAT FLOW	MODIFIED ALSEP	X			
	MASS SPECTROMETER	MODIFIED ALSEP	X			
	TIDAL GRAVIMETER	MODIFIED ALSEP	X			
	LUNAR EJECTA AND METEORITES	MODIFIED ALSEP	X			
S-203	LUNAR SEISMIC PROFILING	MODIFIED ALSEP	X········	··················	··················	········X
S-078	LASER RANGING RETROFLECTOR		X			
S-152	COSMIC RAY EXPERIMENT			X		
S-201	FAR UV CAMERA			X		
S-204	SURFACE ELECTRICAL PROPERTIES				X	
S-198	TRAVERSE MAGNETOMETER					X
	TRAVERSE GRAVIMETER					X

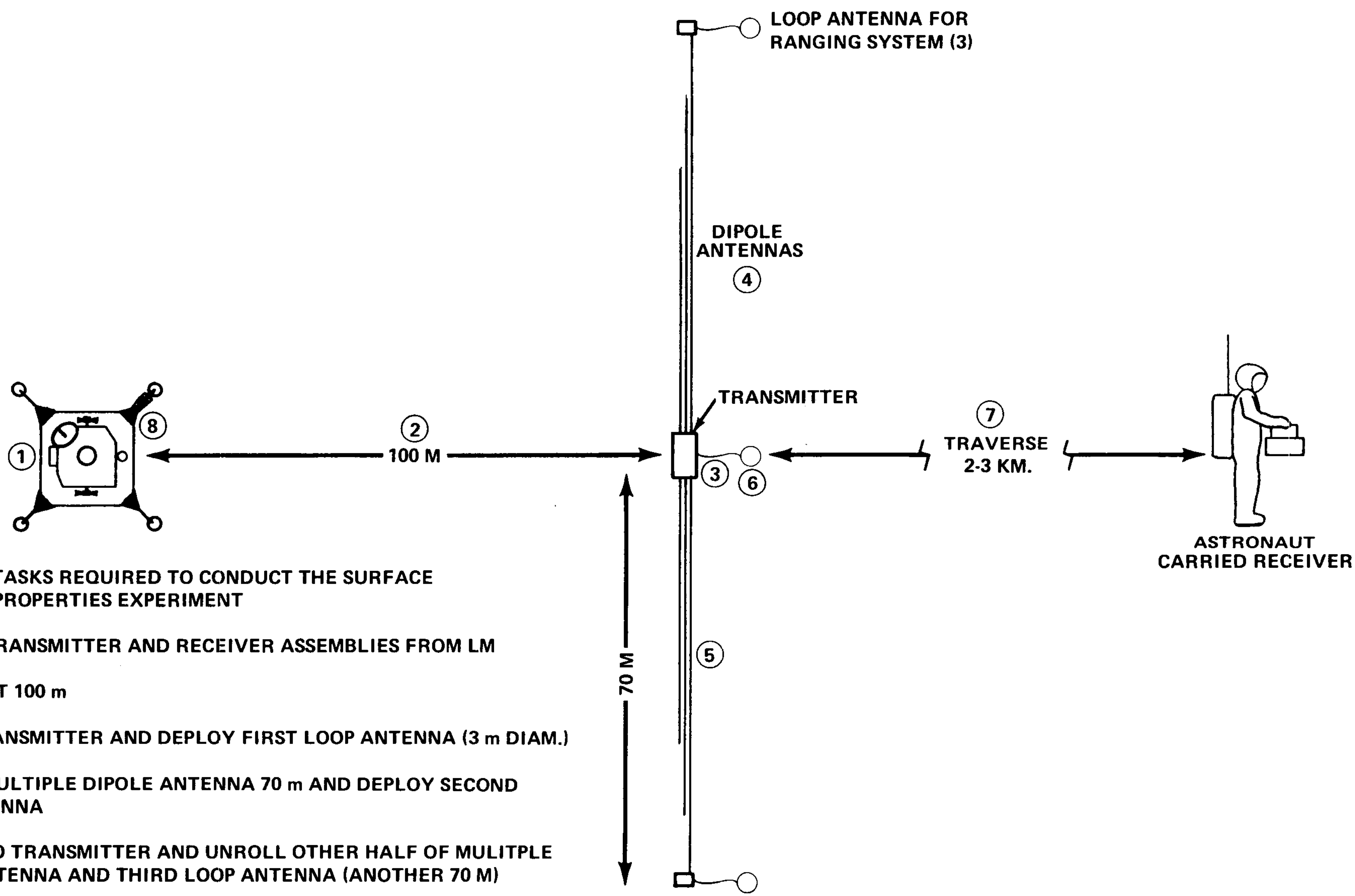
* NOT CONSIDERED IN THIS LIST ARE ENGINEERING EXPERIMENTS, THE GEOLOGY EXPERIMENT AND HAND TOOLS, OR SOIL MECHANICS EXPERIMENTS.

FIGURE 1



APOLLO 12
EXPERIENCE
CDR AND LMP
TYPICAL ALSEP ARRAY A
TIMELINE - CDR AND LMP (REF. 2)
10
MIN
ALSEP OFFLOAD
ALSEP OFFLOAD
20
TRAVERSE PREP.
TRAVERSE
30
TRAVERSE
SITE SURVEY
40
SYSTEM
INTERCONNECT
50
DEPLOYMENT
60
INSTRUMENT AND
CENTRAL STATION
DEPLOYMENT
70
ALSEP ACTIVATION
AND PHOTOGRAPHY
80
90
100
110
120

FIGURE 2



ASTRONAUT TASKS REQUIRED TO CONDUCT THE SURFACE ELECTRICAL PROPERTIES EXPERIMENT

1) REMOVE TRANSMITTER AND RECEIVER ASSEMBLIES FROM LM

2) CARRY OUT 100 m

3) SET UP TRANSMITTER AND DEPLOY FIRST LOOP ANTENNA (3 m DIAM.)

4) UNROLL MULTIPLE DIPOLE ANTENNA 70 m AND DEPLOY SECOND LOOP ANTENNA

5) RETURN TO TRANSMITTER AND UNROLL OTHER HALF OF MULITPLE DIPOLE ANTENNA AND THIRD LOOP ANTENNA (ANOTHER 70 M)

6) RETURN TO TRANSMITTER, CONFIGURE RECEIVER FOR TRAVERSE

7) TRAVERSE NORMAL TO DIPOLES FOR 2-3 KM. (ONE-HAND CARRY OF RECEIVER)

8) RETURN TO LM, UNLOAD TAPE, PACK IN RETURN CONTAINER AND STOW IN LM.

FIGURE 3 - PLAN VIEW OF SURFACE ELECTRICAL PROPERTIES EXPERIMENT DEPLOYMENT

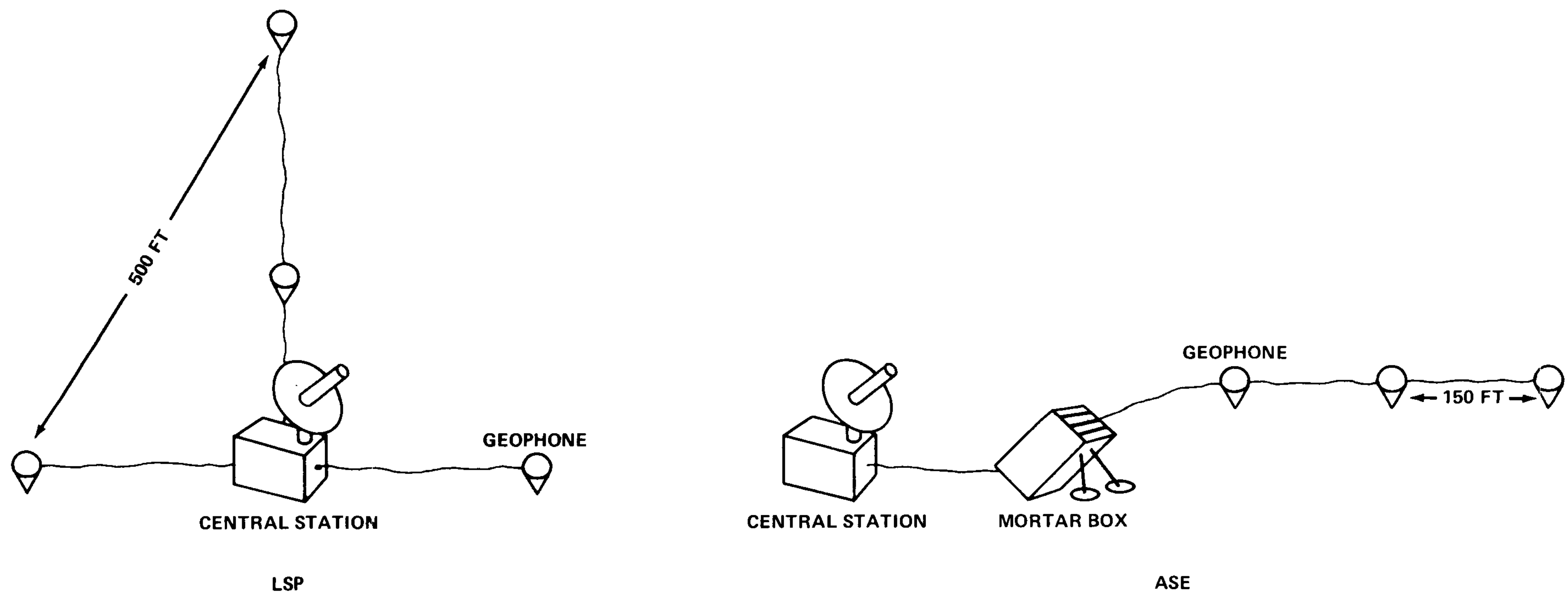


FIGURE 4 - COMPARATIVE PLAN VIEW OF GEOPHONE LAYOUTS FOR LUNAR SEISMIC PROFILING EXPERIMENT AND ACTIVE SEISMIC EXPERIMENT

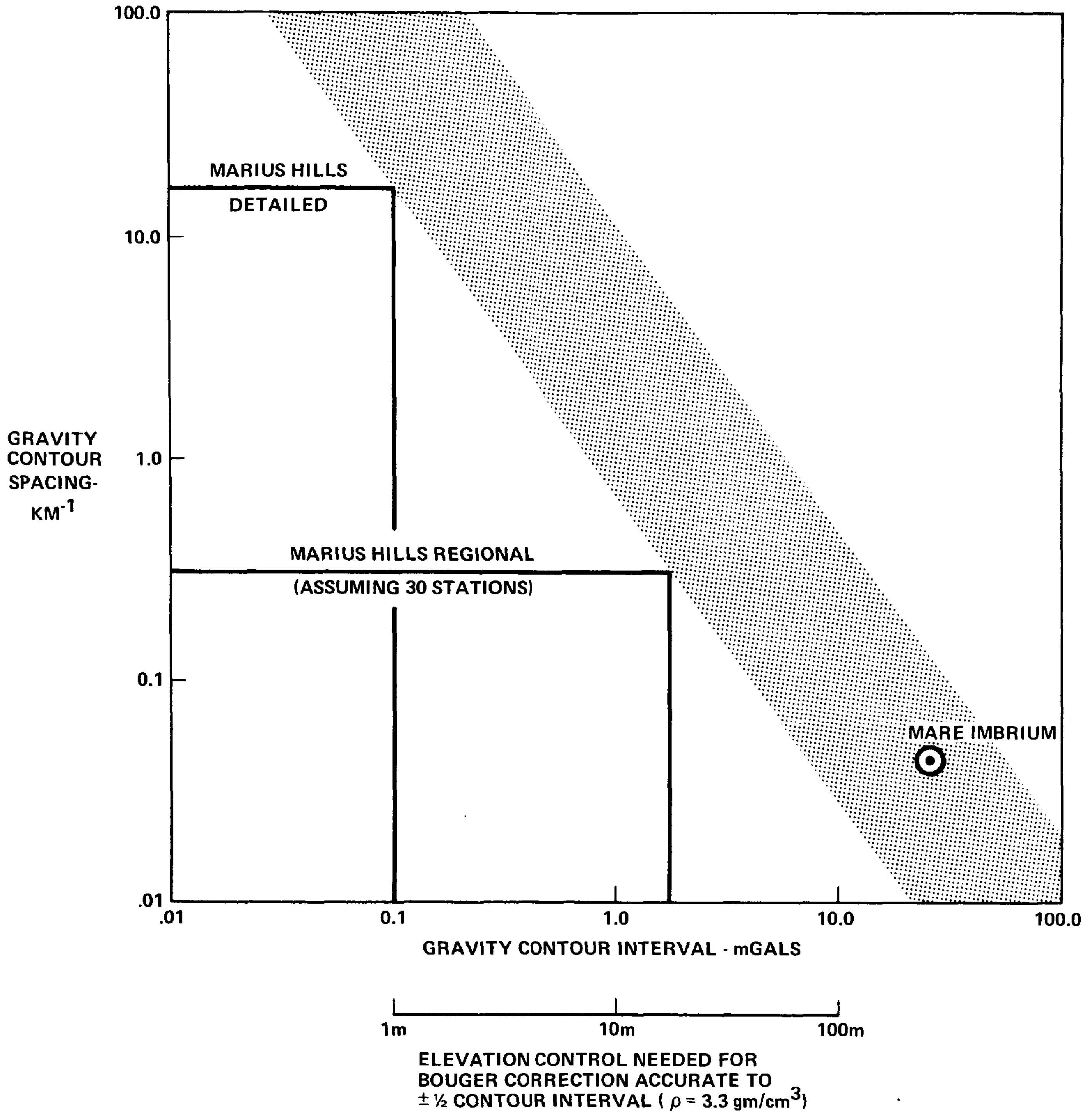


FIGURE 5 - SUMMARY OF SOME TERRESTRIAL GRAVITY SURVEYS WITH THE IMBRIUM MASCON FOR COMPARISON AND THE ANTICIPATED RESULTS FOR TWO TYPES OF SURVEY AT MARIUS HILLS

PHYSICAL CHARACTERISTICS OF THE INSTRUMENTS

	WEIGHT			VOLUME		DATA	POWER
	STOWED	DEPLOYED	RETURNED	STOWED	DEPLOYED		
EMPLACED OBSERVATORY INSTRUMENTS							
ALSEP	230 LBS	170 LBS	–	13,800 IN^3	2500 IN^3 (1)	1060 BPS TRANSMITTED	60 WATTS
LR^3	52 LBS		–	3800 IN^3		NONE	NONE
OTHER EMPLACED INSTRUMENTS							
COSMIC RAY DETECTOR	20 LBS		8 LBS	180 IN^3		NONE	NONE
FAR UV SPECTROSCOPY	25 - 35 LBS		2 LBS	$\sim$1 FT^3 (3)		NONE	INTERNAL BATTERY
SITE SURVEY INSTRUMENTS							
TRAVERSE GRAVIMETER	23 LBS	12 LBS	2 LBS	1000 IN^3	800 IN^3	RECORDED (2)	INTERNAL BATTERY
TRAVERSE MAGNETOMETER	7 LBS	3 LBS	–	$\sim$200 IN^3	$\sim$64 IN^3 (3)	ASTRONAUT READ	"
LUNAR SEISMIC PROFILING (4)	30+ LBS (5)	10 PIECES @ 0.1 TO 10 LBS		500+ IN^3 (5)		NONE	"
SURFACE ELECTRICAL PROPERTIES	20 LBS	7 LBS	2 LBS	$\sim$1 FT^3	$\sim$1 FT^3	RECORDED	"

NOTES:
(1) EXCLUDES CENTRAL STATION AND RTG
(2) SOME DATA, PRIMARILY STATUS, MAY BE READ BY ASTRONAUT
(3) EXCLUDES TRIPOD
(4) TRAVERSE PORTION ONLY
(5) EXCLUDES ELECTRONICS

FIGURE 6

TRAVERSE INSTRUMENT STATION CHARACTERISTICS

	NUMBER OF STATIONS	TYPICAL STATION TIME	DISTANCE DEPLOYED FROM ROVER
TRAVERSE GRAVIMETER	EVERY EGRESS STOP	3 min.	ADJACENT
TRAVERSE MAGNETOMETER	MINIMUM OF 3	INITIAL STATION 20 min. SUBSEQUENT STATION 10 min.	10-20 m
LUNAR SEISMIC PROFILING	10 PER MISSION	2 min.	ADJACENT
SURFACE ELECTRICAL PROPERTIES	REQUIRES A CONTIGUOUS 2km. TRAVERSE - ALONG A PREDETERMINED AZIMUTH		

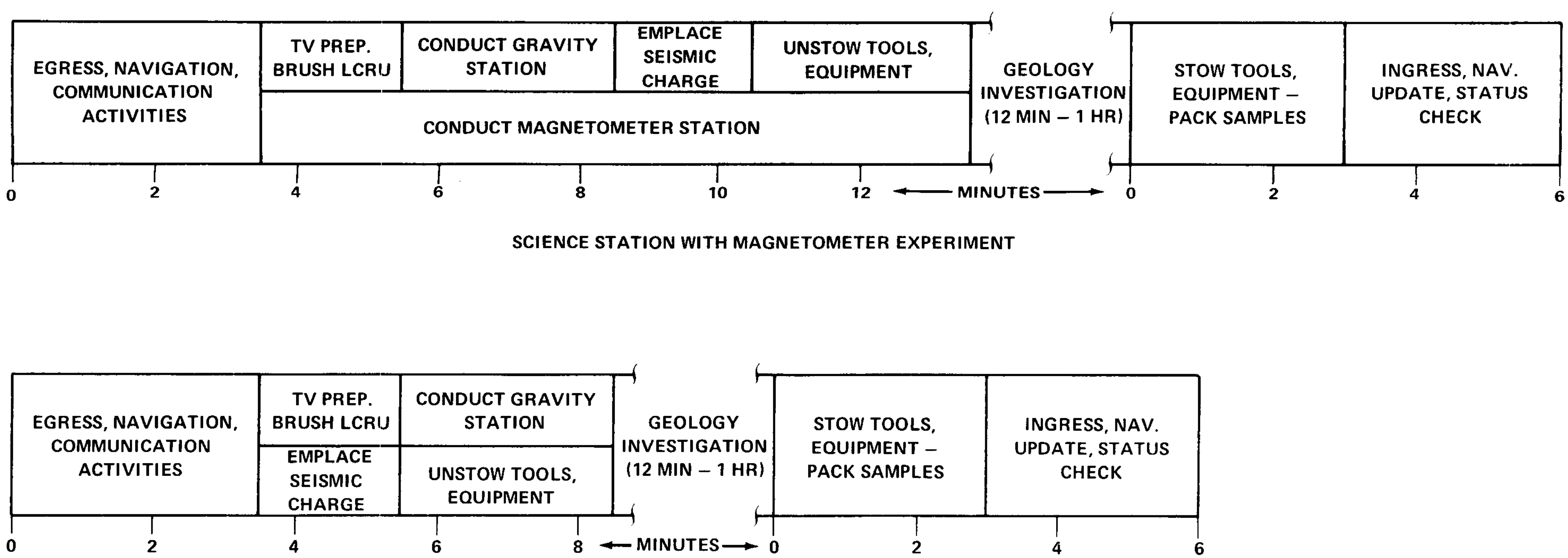
FIGURE 7

	OFFLOAD	CARRY OUT	EMPLACE	ORIENT/LEVEL	ACTIVATE	READ	DEACTIVATE	CARRY BACK	STOW
TRAVERSE GRAVIMETER	X	NO	X	NO	X	NO	X	NO	X
TRAVERSE MAGNETOMETER	X	X	X	X	NO	X	NO	X	X
LUNAR SEISMIC PROFILING	X	NO	X	?	X	NO	NO	NO	NO

INSTRUMENT DEPLOYMENT TASKS
AT EACH STATION

FIGURE 8

STATION ACTIVITY TIMELINES
(ASSUMES REMOTELY CONTROLLED, FIXED MOUNTING TV CAMERA)



SCIENCE STATION WITH MAGNETOMETER EXPERIMENT

SCIENCE STATION WITHOUT MAGNETOMETER EXPERIMENT

FIGURE 9

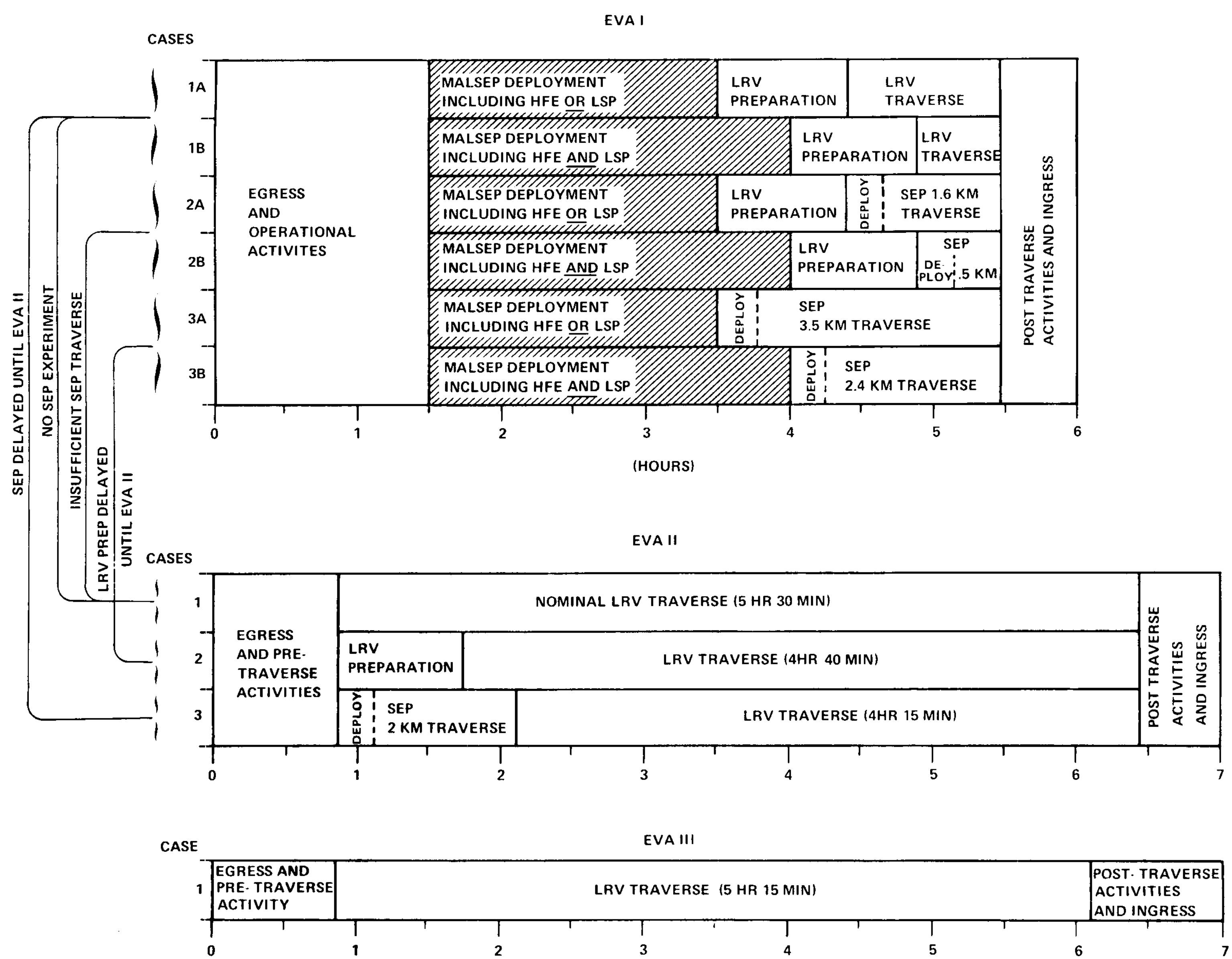

EVA I
CASES
1A
1B
2A
2B
3A
3B
EGRESS AND OPERATIONAL ACTIVITES
MALSEP DEPLOYMENT INCLUDING HFE OR LSP
MALSEP DEPLOYMENT INCLUDING HFE AND LSP
LRV PREPARATION
LRV TRAVERSE
DEPLOY
SEP 1.6 KM TRAVERSE
SEP
DE-PLOY
.5 KM
SEP 3.5 KM TRAVERSE
SEP 2.4 KM TRAVERSE
POST TRAVERSE ACTIVITIES AND INGRESS
(HOURS)
SEP DELAYED UNTIL EVA II
NO SEP EXPERIMENT
INSUFFICIENT SEP TRAVERSE
LRV PREP DELAYED UNTIL EVA II
EVA II
CASES
EGRESS AND PRE-TRAVERSE ACTIVITIES
NOMINAL LRV TRAVERSE (5 HR 30 MIN)
LRV PREPARATION
LRV TRAVERSE (4HR 40 MIN)
SEP 2 KM TRAVERSE
LRV TRAVERSE (4HR 15 MIN)
POST TRAVERSE ACTIVITIES AND INGRESS
EVA III
CASE
EGRESS AND PRE-TRAVERSE ACTIVITY
LRV TRAVERSE (5 HR 15 MIN)
POST-TRAVERSE ACTIVITIES AND INGRESS

FIGURE 10

LUNAR SURFACE SCIENCE PROGRAM
EXPERIMENT/MISSION ASSIGNMENT MATRIX

EXPERIMENT NUMBER AND TITLE		APOLLO MISSION NUMBER 11	12	13	14	15	16	17	18	19
S–031	PASSIVE SEISMIC (4)	X	X	X	X	X	X	X	X	X
S–033	ACTIVE SEISMIC (4)				X		X			
S–203	SEISMIC PROFILING (3) (4) (5)							X		X
S–034	MAGNETOMETER (4)		X			X	X		X	X
S–198	LUNAR HAND-HELD MAGNETOMETER				X		X		X	
S–035	SOLAR WIND SPECTOMETER (4)		X			X				
S–036	SUPRATHERMAL ION DETECTOR (4)		X		X	X				
S–037	HEAT FLOW (4)			X			X	X	X	
S–038	CHARGE PARTICLE LUNAR ENVIRONMENT (4)			X	X					
S–058	COLD CATHODE IONIZATION (4)		X	X	X	X				
S–059	LUNAR GEOLOGY INVESTIGATION (5)	X	X	X	X	X	X	X	X	X
S–078	LASER RANGING RETRO-REFLECTOR	X			X		X			
S–080	SOLAR WIND COMPOSITION	X	X	X	X					
S–151	COSMIC RAY DETECTOR (HELMETS)	X								
S–201	FAR UV CAMERA/SPECTROSCOPE (3)							X		
S–184	LUNAR SURFACE CLOSE-UP STEREO CAMERA	X	X	X	X	X	P_1	P_1	P_1	P_1
M–515	LUNAR DUST DETECTOR (4)		X	X	X	X	X			
S–152	COSMIC RAY DETECTOR (1) (3)						X			X
S–202	LUNAR EJECTA AND METEORITES (3) (4)							X	X	
S–204	SURFACE ELECTRICAL PROPERTIES (3)								X	X
S–200	SOIL MECHANICS (2) (3) (5)				X	X	X	X		
	MASS SPECTROMETER (4)								P	P
	TRAVERSE GRAVIMETER (5)								P	P

X – APPROVED EXPERIMENT
P – PROPOSED EXPERIMENT
P_1 – PROPOSED AS A FACILITY RATHER RATHER THAN EXPERIMENT

(1) COMBINED EXPERIMENT OF THREE PREVIOUSLY PROPOSED EXPERIMENT–LOW ENERGY COSMIC RAY, EFFECT OF LOW ENERGY, AND LOW ENERGY HEAVY COSMIC RAY
(2) INVOLVES ONLY PI EVALUATION OF DATA GATHERED FROM EXISTING SOURCES AND NOT THE DEVELOPMENT OF NEW INSTRUMENTATION AND HARDWARE
(3) MSFEB APPROVED–3/30/70
(4) PART OF ALSEP PACKAGE
(5) CAN BE PERFORMED ON OR ESPECIALLY ADAPTED FOR USE WITH LRV

FROM A PRESENTATION BY MSC/S&AD

FIGURE 11

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SUBJECT: Characteristics of Lunar Surface Experiments for Apollo Missions 16-19

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